Because changes in intrastate output affects interstate costs, there is conceptually no way to define TFP growth separately by jurisdiction. And since one cannot define distinct interstate and intrastate productivity growth rates, there can be no adjustment to total company TFP growth to approximate interstate productivity growth.

1. Separability imposes restrictions on the production process for a multiproduct firm that do not hold for telecommunications technologies.

Economic theory shows clearly that TFP growth for subsets of services in a multiproduct firm can be defined only in very restrictive circumstances that certainly do not hold for telecommunications firms. In economic theory, productivity growth is measured with reference to a production function which specifies the maximum output that can be produced from given quantities of inputs. Using that production function, total factor productivity growth is the difference between the rates of growth of a revenue-weighted index of maximum output quantities and an expenditure-weighted index of input quantities. If there were only two outputs: interstate and intrastate services, it would not be meaningful to speak of individual TFP growth rates for interstate and intrastate services unless the production function can be written in a particular and very restrictive form in which:

- all outputs can be unambiguously separated into intrastate and interstate services;
- all inputs can be unambiguously separated into intrastate and interstate factors of production; and
- changes in intrastate inputs do not affect interstate output and changes in interstate inputs do not affect intrastate output.

Mathematically, these conditions imply that the cost function for the firm can be written as the sum of individual cost functions for interstate and intrastate services:

$$C(Q_{inter}, Q_{intra}, P_L, P_K, P_M) = C_1(Q_{inter}, P_L, P_K, P_M) + C_2(Q_{intra}, P_L, P_K, P_M)$$

where P_L, P_K, and P_M are the prices of labor, capital and materials, Q_{inter} and Q_{intra} are quantities of interstate and intrastate outputs and $C_i(Q, P_L, P_K, P_M)$ represents the minimum cost of producing output Q with given factor prices P_L, P_K and P_M. These requirements are known as "separability" restrictions in economic theory, and in particular, they mean that the marginal rate of substitution among interstate factors of production must be independent of the level of intrastate demand (and vice versa). The known presence of economies of scope among interstate and intrastate services means that the cost function cannot be separable, and TFP growth cannot be measured independently for interstate and intrastate services.

As recognized in the *FFN*, interstate and intrastate telecommunications services are supplied using a high proportion of common facilities, and such technologies are, in fact, *not* separable in the sense defined above. Interstate and intrastate usage services are produced using the same facilities and expenses. An increase in demand for interstate carrier access leads to precisely the same changes in investment and expenses as an increase in the demand for intrastate carrier access or, indeed, for local usage. In these circumstances, it is impossible to distinguish between the productivity growth rates of intrastate and interstate services. If each additional minute of interstate service requires the same increase in inputs as an additional minute of interstate service, then productivity growth in the two sectors will be the same.

Note that this result holds irrespective of the output growth rates of the two services. Even if intrastate output is constant, if the identical technology is used to produce intrastate and interstate services, interstate and intrastate services would experience the same growth in total factor productivity, in the sense that the change over time in the amount of output produced per unit of input would be the same. An addition to the rate of growth of interstate output would lead to higher total factor productivity growth for intrastate as well as interstate services.

2. Jurisdictional separations do not provide a basis for productivity analysis

Outputs can be assigned consistently to interstate and intrastate jurisdictions, although the distinction may have little meaning to customers.[29] The difficulty for productivity analysis is that the costs associated with producing intrastate and interstate

[29] For example, the local distribution of interstate toll calls is jurisdictionally interstate under the Commission's rules, but the calls are functionally identical to the local distribution of intrastate toll calls.

services cannot be separated into corresponding intrastate and interstate components. The Commission's Part 36 Rules do not jurisdictionally separate costs for the purpose of setting prices. They do not reflect cost causation, and interstate costs do not even approximate the economic costs of supplying interstate services. Productivity growth measures based on separated costs would be distorted by changes in the separations formulas and factors and would provide no meaningful information about the productivity growth of interstate services.

Consider, for example, the recent history of jurisdictional separations. From the beginning, the interstate jurisdiction was synonymous with long distance toll service. Thus costs allocated to the interstate jurisdiction were recovered from long distance charges while costs allocated to the intrastate jurisdiction could be recovered from intrastate usage charges or from flat-rated monthly charges. Until *Smith v. Illinois Bell* in 1930, none of the costs of local service were assigned to long distance services. The first separations manual was adopted in 1947, and in response to the perceived need to hold down local rate increases, the industry steadily increased the portion of local costs assigned to the interstate jurisdiction.[30] By 1982, the presence of competition in interstate long distance markets made increasing subsidies to local service difficult to sustain, and the FCC froze the subscriber plant factor portion of the separations formula, reducing it to a common 25 percent gross allocator in a transition from 1983 to 1986.

The intention of jurisdictional separations was thus to determine an appropriate amount of local exchange costs to be recovered from long distance revenues. There was and is no pretense that jurisdictionally interstate costs bear any relation to the forward-looking incremental or total costs of supplying interstate services. For example, 25 percent of non-

[30] The percent of non-traffic sensitive (NTS) plant assigned to the interstate jurisdiction was originally set at the interstate minutes of use (SLU) proportion. This proportion increased steadily between 1950 and 1980 from 1.8 times SLU in the Charleston Plan (1952) to 2.5 times SLU in the Denver Plan (1965) to 3.2 times SLU in the FCC Plan (1968), culminating in 3.3 times SLU in the Ozark Plan (1971). For a history of jurisdictional separations, see James W. Sichter, *Separations Procedures in the Telephone Industry: The Historical Origins of a Public Policy*, Program on Information Resources, Harvard University, Cambridge, Massachusetts, Publication P-77-2, January 1977 or C.L. Weinhaus and A.G. Oettinger, *Behind the Telephone Debates*, Norwood, New Jersey: Ablex Publishing Corporation, 1988.

traffic sensitive (NTS) accounting costs are assigned to the interstate jurisdiction even though these costs are not sensitive to the volume of interstate services or even to the presence or absence of interstate services in their entirety. Measures of productivity growth for interstate services would be affected by the rate of growth of NTS plant, and yet there is no causal connection between the growth of interstate output and changes in NTS plant.

When the production process is not separable between interstate and intrastate services, interstate TFP growth is undefined. Measuring it is like trying to find a black cat in a dark room where there is no cat. It is not merely very difficult; it can't be done.

If it could be done—though it can't—any method of measuring jurisdictionally interstate TFP growth would have to adjust investment and expenses for changes in the separations rules. Obviously a change in a separations formula that shifts investment or costs towards the interstate jurisdiction does not represent a reduction in interstate productivity growth in any meaningful sense of the word. In addition to adjusting for changes in the rules, additional adjustments would have to be made for ordinary changes in separations factors. The Commission's Part 36 Rules assign investment and costs to the interstate jurisdiction depending on factors such as the percentage of interstate use. In practice, special studies are performed by telephone companies at various intervals of time to calculate factors to be used in the formulas. A change in a factor would change measured productivity growth—all else equal—and since the change in the factor bears no necessary relationship with a change in the forward-looking economic cost of supplying interstate service, such changes would also bias the measurement of productivity growth.

In short, the jurisdictional assignment of costs through Part 36 of the Commission's Rules does not represent an economically meaningful assignment of costs to the categories corresponding to outputs of interstate and intrastate services. Changes in separated costs or investment generally have no bearing on corresponding changes in the relative costs of interstate and intrastate services, and using such costs in a TFP study would produce economically meaningless results. As long as interstate and intrastate services are produced using common costs and the same technology, there is no way to identify separate productivity growth rates for interstate and intrastate services.

3. Different output growth rates for different services do not imply different productivity or unit cost changes.

It is generally recognized that output growth is a key determinant of the rate of growth of TFP. For example, the 1989 NERA study filed in CC Docket No. 87-313 found that a one percent increase in the rate of growth of usage was associated with about a 0.5 percentage point increase in the rate of growth of TFP.[31] Similar results were reported in the Christensen study for local exchange carriers filed in 1994; that study concluded that "a one percentage point decrease in output will lead to a reduction in TFP growth of between .3 and .5 percentage points."[32] With this background, the Commission seeks comment in the *FFN* (at ¶ 65) regarding adjustments that might be made to an aggregate firm-level historical TFP growth estimate to reflect differences in intrastate and interstate service growth rates.

First, it is important to understand the observed relationship between rates of growth of output and rates of growth of TFP. Faster growth in usage (interstate or intrastate), for example, leads to a more rapid replacement of network switches and trunks which are common facilities used to produce both interstate and intrastate usage services. Hence more rapid interstate output growth leads to more rapid total company productivity growth. In exactly the same manner, more rapid intrastate usage growth leads to the same increased growth in total company TFP. Thus, even if interstate and intrastate services were separable (so that we could identify separate productivity growth rates—which we cannot), their TFP growth rates would be the same and would not depend on which service was actually growing more rapidly over any particular historical period.

Second, suppose that interstate and intrastate message *usage* services were identical (and thus experienced identical historical TFP growth rates). An additional component of overall intrastate output is related to lines, and it is correct that the growth in lines has

---

[31] National Economic Research Associates, Inc., "Analysis of AT&T's Comparison of Interstate Access Charges Under Incentive Regulation and Rate of Return Regulation." Filed as Reply Comments regarding the FCC's *Report and Order* and *Second Further Notice of Proposed Rulemaking* in CC Docket 87-313, August 3, 1989.

[32] L.R. Christensen, P.E. Schoech, and M.E. Meitzen, "Productivity of the Local Operating Telephone Companies Subject to Price Cap Regulation," Christensen Associates, May 3, 1994, p. 23.

significantly lagged the growth in usage services over the post-divestiture period. Does the inclusion of line-related services in the measure of intrastate output suggest that interstate TFP growth—if identifiable—would be greater than the aggregate firm TFP growth? The answer is no because the production process of a multiservice telecommunications firm cannot be separated between line and usage-related outputs.[33] If the production process is not separable, it makes no sense to speak of productivity growth for lines or usage individually.

In conclusion, TFP growth is undefined for intrastate and interstate services, and attempts to adjust aggregate measures of TFP growth to offset differential rates of output growth or different average margins between price and cost can only be described as arbitrary. Because separate productivity growth rates for interstate and intrastate services do not exist, it is futile to ponder how to adjust an aggregate TFP measure to approximate the non-existent separated growth rates.

B. Productivity Growth Cannot be Measured Independently for Regulated and Nonregulated Services Produced Using Common Facilities

The FCC 1987 *Joint Cost Order*[34] established rules (set out in Part 64 of the Commission's Rules) to separate costs of regulated and nonregulated services, including both incremental costs that can be assigned on a cost-causative basis and common costs that cannot. The Order requires large LECs to file cost allocation manuals (CAMs) that detail each company's implementation of the rules and to submit to an annual independent audit to attest that the firm complies with the manual. Like the Part 36 jurisdictional separations rules, these Part 64 rules assign costs to regulated and nonregulated services on an other-than-cost-causal basis.

---

[33] Some important cost-reducing technical changes are common across lines and usage, e.g., developments in optical fiber transport and in installation and maintenance savings through process re-engineering initiatives.

[34] *Joint Cost Order*, 2 FCC Rec. at 1298.

However, unlike the Part 36 rules, FCC accounting rules do avoid splitting revenues and costs of regulated and unregulated services that share facilities or costs. According to the Part 32 accounting rules, revenues and expenses are booked to accounts within the regulated telephone company whenever the function in question entails costs that are common with the production of a regulated service. Only when production of the service has no shared or common costs with a regulated service would its revenues and expenses be recorded in a separate set of accounts.[35] Part 64 rules are then used to allocate the balances in accounts between regulated and nonregulated sectors, and Part 36 rules are applied to the regulated balances remaining in these accounts (sometimes called "subject to separations" accounts) to effect jurisdictional separations.

Paragraph 70 of the FFN suggests that because

> (w)ith respect to other unregulated services, however, the production functions may differ substantially from those of regulated services since nonregulated services include foreign service offerings and noncommunications services

it might be

> possible and reasonable to exclude some or all nonregulated services from the TFP calculation even though we decide to include intrastate services in the calculation.

To the extent that Part 32 accounting rules recognize and idenify when regulated and nonregulated services share no common costs or facilities, it is reasonable to treat the production function of the telephone company as separable between regulated and nonregulated services—in the sense that its cost function can be written as the sum of independent cost functions for the aggregate of regulated services and the aggregate of nonregulated services. Under no likely conditions, however, could Part 64 separated data be used to measure the costs attributable separately to individual regulated or unregulated services because of the existence of a shared production funtion (joint and common costs).

[35] See, e.g., 47 CFR Section 32.4999(l).

IV. THE HISTORICAL REVENUE METHOD SHOULD NOT BE USED TO SET A PRODUCTIVITY TARGET

Although it tentatively adopted the TFP-based approach for establishing the X factor, the FCC is seeking comments on a number of other approaches, including the Historical Revenue Method.[36] In particular, Issue 2a asks:

- Is the Historical Revenue Method Superior to a TFP-based approach for developing an X-factor?

The answer is no. The Historical Revenue Method provides perverse productivity incentives: essentially the same disincentives of traditional cost-plus regulation. In addition, the deviations between accounting and economic costs introduce serious measurement errors so that the method is an extremely poor approach to establish a productivity factor for a price cap plan.

We elaborate by addressing the specific issues addressed in ¶s 80 - 83. In particular, ¶81 deals with the fundamental issue of incentives, and ¶ 83 deals with the mathematical basis for the approach. Paragraphs 80 and 82 address implementation details in the event that the approach is adopted. We address the paragraphs in this order.

A. Productivity Incentives

Paragraph 81 asks: "Does the Historical Revenue Method provide adequate incentives for LECs to increase productivity and become more innovative?" The answer is no. As we explained in NERA's June 1994 reply comments, because this method resembles traditional regulation, it does *not* provide proper efficiency incentives. We repeat our earlier analysis of this issue here.

In the 1994 review, several parties asserted that LEC earnings had risen under the price cap plan or were simply too high, and they proposed an increase in X to resolve these problems. Both AT&T and GSA based their productivity offset recommendations on a direct assessment of the LECs' actual accounting earnings performance during the price cap period.

---

[36] The method was proposed by AT&T (and also GSA) and has been called the Direct Method by its proponents.

While employing somewhat different methodologies, both answered the question: what would the X factor have to have been for the LECs to have earned the target return (11.25 percent) during the price cap period. Both then proposed a mid-course adjustment to the Commission's productivity offset based on that calculated historical X.

That proposal represented a gross misunderstanding of how incentive regulation works; if implemented, it would eviscerate the Commission's attempted regulatory reform and institute in its place, traditional cost-plus regulation with a three-year lag. The very design of incentive regulation requires that the LECs *not* be required to forfeit the entirety of the gains obtained from their own improved performance. Hence measurements of achieved productivity growth should have only a *limited* role: to serve as a diagnostic measure of whether the original parameters of the plan were seriously in error. There are two reasons for this limitation:

(i) productivity growth exhibits fairly large year-to-year variations, so that most observed deviations from the expected value are well within the normal range. It would be senseless to vary parameters of the plan to track random fluctuations in annual productivity growth; and

(ii) unusually large productivity gains could be the result of management effort. Adjusting the plan subsequent to this effort would severely erode the incentives of the plan to the point of creating a thinly-disguised version of traditional cost-plus regulation.

The original price cap plan contemplated a wide range of acceptable earnings outcomes: a floor was established at 10.25 percent, 50/50 sharing of earnings would begin at 12.25 percent, and earnings were capped at 16.25 percent. Earnings within this range were permitted to deviate (up or down) from 11.25 percent, and the acceptable degree of deviation was not unintentional. Indeed, it constituted the essential difference between the price cap plan and ordinary rate of return regulation. If the range of acceptable earnings outcomes had been smaller—e.g., if it shrunk to zero (around 11.25 percent)—the price cap plan would have operated exactly as theoretical rate of return regulation.[37] The price cap formula would have adjusted prices every year, but earnings adjustments would have ensured that prices in total changed just as they would have changed had rate of return regulation continued. Thus earnings that deviated from 11.25 percent but remained in the range contemplated by the plan were not considered excessive or deficient, and allowing earnings to deviate from 11.25 percent is an essential component of the plan.

It is noteworthy that according to AT&T's data presented in the 1994 Review, no RBOC's rate of return fell outside this range, averaged over the price cap period. In fact, the average rate of return for the price cap companies fell comfortably in the center of the range. Adjusting a plan on the basis of actual outcomes that are clearly within the range contemplated by the plan would have simply been a return to the bad old days of traditional cost-based regulation, which the Commission rightly rejected as antiquated and in need of change.

Another problem with using earnings in the way contemplated by the historical revenue method is that LEC earnings—as measured by regulatory accounting rules—do not pretend to measure economic profit and are notoriously poor proxies for it. Moreover, *changes* in accounting earnings are also a poor measure of changes in economic profit. First, economic profit is not defined for interstate services because there is no economic basis upon which to split common costs between interstate and intrastate services. Second, the accounting treatment of depreciation for regulated LECs is based on asset lives that are currently too long and have historically been too long, so that LEC accounting profits are overstated relative to economic profits. As telecommunications markets become more competitive, market forces will undertake a more realistic appraisal of the LEC capital stock, and as asset lives are reduced, the associated changes in accounting profits will be again a poor measure of changes in economic profits.[38] Third, regulated earnings are affected by numerous accounting conventions, so that a firm's decision to accelerate the depreciation

[37] This result holds irrespective of the level of the authorized rate of return. If the acceptable range of earnings shrank to zero around 12.25 percent, the outcome would be indistinguishable from cost-plus regulation using 12.25 percent as the authorized rate of return.

[38] See, for example, Riva Atlas, "Honesty isn't such a bad policy," *Forbes*, July 4, 1994, p. 118.

expense associated with an asset would affect measured productivity growth in this method but would not, in reality, affect the growth rates of outputs, inputs or actual productivity.[39]

A second problem with inferring a productivity differential from earnings data is that the calculation presupposes that all other aspects of the plan perform correctly. In particular, if some exogenous cost changes—positive or negative—were not accounted for under the price cap plan or if their effect on costs beyond their effect on the GDP-PI were calculated incorrectly, one could no longer infer the level of the achieved historical productivity offset from data on earnings.

Because price cap regulation decouples prices from accounting costs, regulated firms operate under efficiency incentives similar to those facing unregulated firms. However, the efficiency benefits from price caps depend on managers having confidence that superior cost savings will not ultimately be taken away through inappropriate adjustments to the plan. For example, if management believed that superior realized productivity would trigger an increase in the productivity target in the future, the efficiency incentives would be severely eroded.

While the actual performance (including the change in productivity) of the LECs during the price cap period may be germane to the review of the program, the results must be interpreted in the context of the Commission's intent in establishing the plan. In order to ensure long-term stability and to avoid a return to traditional cost-plus regulation, it is absolutely essential that the productivity gains realized under price caps not be used to recalculate a firm's price cap productivity target. For example, suppose the LEC industry implemented a cost-saving program that lowered the *level* of inputs by one percent, but did not affect the rate of change in inputs in the future. Such a change would show up as a one percent improvement in productivity in the year it occurred. If this measurement caused the productivity target to increase by one percent, the LECs would be forced to give back their

[39] A TFP study—like the Christensen Associates study filed in this Docket—that uses economic depreciation in its calculation of the capital stock is not affected by these accounting conventions that would distort the type of analyses presented by AT&T and GSA and now referred to as the Historical Revenue Method.

Method.

increased earnings and would be committed to make similar additional cost savings in every future year. Returning earnings from cost reductions would be exactly what occurs under traditional cost-plus regulation with regulatory lag and would constitute a failure to reward efficiency improvements that the Commission sought to encourage with price caps. Moreover, it would be wholly incorrect to incorporate a one-time cost reduction into a long-term productivity offset by effectively assuming that the cost reduction would continue to take place in every year.

B. Comparison of X factors from TFP and Historical Revenue Methods

Paragraph 83 deals with the mathematical relationship between a TFP-based *X* factor and one based on the Historical Revenue Method. Because of the distortions introduced from using accounting data (including accounting measures of depreciation, sunk costs, authorized cost of capital, calculation of interstate earnings, etc.), there is no precise mathematical relationship. The use of accounting data in place of the correct economic data (which *is* used in a proper TFP study) introduces an "apples to oranges" feature into any attempt to compare the methods rigorously.

If, hypothetically, the Historical Revenue Method were used with *economic* cost measures, there could be a direct comparison. By definition, TFP accounts for all costs, including the cost of capital. Therefore, on average over sufficiently long time periods, revenues would just equal costs and there would be no economic profit (i.e., the firm would earn its cost of capital). Therefore, given a correct measure of the *economic* (not accounting) cost of capital, an earnings-based method could conceivably produce a backward-looking measure of productivity achievement equivalent to that produced by the TFP-based method. However, to date, no party has proposed using such a version of the Historical Revenue Method.

There are several qualifications to this statement of equivalence. First, the Historical Revenue Method measures a *deviation* from an established productivity target and actual results. So unlike an ordinary TFP-based calculation of X, this method cannot stand on its own, and it is only useful when a TFP-based measure of the productivity target is already available. Second, when added to the target, the results of the Historical Revenue Method measure the difference between the output price growth of the industry and US output price growth (GDP-PI); they do not measure TFP growth directly. The relationship between the output price growth differential and telecommunications industry TFP is the following:

$$\mathbf{TFP_I = X^{HRM} - GDP\text{-}PI + w_I}.$$

That is, industry productivity growth (TFP_I) consists of the sum of

(i) the difference between the result of the Historical Revenue Method (X^{HRM}) and economy-wide output price inflation (*GDP-PI*) and

(ii) the level of the input price inflation rate (w_I) of the telecommunications industry.

Third, in order for this equivalence to hold, all of the problems of using accounting data to represent economic concepts for a subset of the firm's services would have to be overcome, including measuring economic depreciation, valuation of sunk costs, measuring the cost of capital, and the inability to measure profits meaningfully for interstate services in the presence of common costs. Finally, the above hypothetical implementation of the Historical Revenue Method is applied to the firm as a whole. AT&T's application of this method to a subset of LEC services (interstate carrier access) is invalid for the same reasons that productivity studies for a subset of the firm's services are generally invalid. Because these requirements for equivalence are not satisfied for telecommunications firms, the Historical Revenue Method will yield biased estimates of TFP growth for such firms and should not be used to set a productivity target in a price cap plan.

V. The Historical Price Method is the Dual of the TFP Method

While the economic theory of duality shows that productivity can be calculated from either the differential rates of growth of input and output quantities or prices, there are practical differences in the calculations which favor using quantity indices to measure changes in TFP. The *FFN* explores this relationship (at ¶s 84-86) between the historical price method and the TFP method for determining a productivity offset in the annual price adjustment formula for a price-cap-regulated firm. In economic theory, TFP growth and the change in unit costs can be measured using the same set of basic assumptions and the relationship between input and output quantities or input and output prices. In his classic exposition of the theory of total factor productivity measurement, D.W. Jorgenson begins with the identity that the value of output is equal to the value of input (equation (1)). He then differentiates this identity with respect to time to derive the change in TFP as the difference between Divisia quantity indexes of outputs and inputs. In a footnote, he observes that

> Any index of total factor productivity may be computed either from quantity indexes of total output and total input or from the corresponding price indexes. The whole analysis that follows could be carried out in an entirely equivalent way, using price indexes instead of quantity indexes.[40]

In particular, measurement of the change in TFP by either the price or quantity method requires the assumption that the value of input equal the value of output in each period—or at least that the data be adjusted so that this identity holds approximately in the historical period.[41]

These basic facts from the economic theory of duality have several practical consequences. First, the apparent ability of the historical price method to produce a productivity offset or a measure of productivity growth *for an individual service*—or for

---

[40] D.W. Jorgenson, "The Embodiment Hypothesis," *The Journal of Political Economy*, Vol. LXXIV, February 1966 at 2-3.

[41] This dependence on the constant equality of revenue and cost over time makes intuitive sense. If a firm were to increase economic earnings rather than lower prices to reflect productivity growth, the price method applied to that data would underestimate true productivity growth. Recall that the Frentrup-Uretsky study adjusted prices to hold earnings constant. The Christensen study accomplishes this by using an independent measure of the cost of capital.

interstate carrier access services as a group—is illusory. When output price data are adjusted to keep earnings constant across the historical period, accounting costs must be assigned to individual services.[42] That assignment is no different—in principle—from the measurement of interstate access TFP growth from Part 36 and Part 69 cost and revenue data, which is acknowledged to be inappropriate. Second, while duality implies that TFP growth measured by quantities and prices will be the same, it does not suggest that failure of any of the assumptions of the method will have the same effect on the two TFP growth measures.

For example, suppose economic earnings vary from year to year during the historical period. TFP growth measured by quantities could differ markedly from TFP growth measured by prices. If prices are adjusted in each period to keep measured economic earnings constant, errors in the adjustment would affect TFP as measured by prices more than TFP as measured by quantities. Using the historical price method, TFP growth is calculated from *changes* in prices (i.e., the difference between the rates of growth of input and output prices). Using the quantity method, prices enter the TFP growth calculation only

(i) as part of the revenue and expenditure weights used to calculate aggregate quantity indices of outputs and inputs; and

(ii) as *levels* rather than annual changes.

Thus errors in measuring input or output prices (or adjusting output prices to keep accounting earnings constant) have a larger effect on TFP growth as measured by price rather than quantity. Possibly for these reasons, it is instructive to note that, without exception, empirical studies of productivity growth use quantity indices rather than price indices.[43]

Third, the practical decision whether to base historical measurements on quantities or prices must take into account the use to which the measurement will be put. In the present

[42] Thus when NERA and Frentrup-Uretsky calculated X using the historical price method in CC Docket No. 87-313, they adjusted prices to hold earnings constant, and that adjustment required the calculation of the total cost of interstate switched access services. The calculation therefore erroneously assigns a portion of the fixed costs of the LECs to interstate switched access services and presented arbitrary and incorrect estimates of TFP.

[43] See, for example, D. Jorgenson, F. Gollop and B. Fraumeni, *Productivity and U.S. Economic Growth*, Cambridge: Harvard University Press, 1987, at 4 and 152-159.

exercise, the results will be used essentially to forecast future values of productivity growth to determine a reasonable target productivity growth for the price-cap regulated LECs. Since productivity growth—relative to U.S. average productivity growth—is the ultimate source of real price reductions in any market, it is preferable to study productivity growth directly, rather than indirectly through the price changes that follow from productivity growth. In particular, possible differences between the historical period and the future will be easier to quantify directly in terms of productivity growth than indirectly in terms of output price growth.[44]

Finally, the duality of price and output-based measures of productivity growth can be used as to check results. As discussed above, we cannot use duality to reconcile the historical price calculations for interstate switched access services with the quantity-based productivity measures calculated by Christensen: the latter applies to all the firm's services and would be comparable only to a price-based productivity study performed on all of the firm's services.

It is straightforward to compare a price-based measure of the achieved *X* for the telecommunications industry with the historical *X* calculated by Christensen. Indeed, the Commission Staff has already performed such a comparison: the Spavins-Lande studies filed in CC Docket No. 87-313 are long run measures of the *X* achieved by the telecommunications industry.[45] As updated through 1993 in the NERA Reply Comments, the long run (1929-1993) productivity offset calculated from telecommunications industry price data averaged about 2.1 percent, unchanged from the Spavins-Lande finding for the 1929-1987 period. Applying the method to the post-divestiture period, we find that the Spavins-Lande historical price-based value of *X* for the period examined in the Christensen direct studies (1984-1993) is 2.4 percent which corresponds reasonably closely with the value of *X* proposed by Dr. Christensen which uses the long run input price differential of 0. This

[44] This difference is particularly relevant when prices were regulated differently between the historical period and the future. Much of the work in the original studies in CC Docket 87-313 using the historical price method was done to correct measured prices for changes over time in regulatory rules and procedures.

[45] *Supplemental Notice of Proposed Rulemaking*, CC Docket 87-313, March 12, 1990, Appendix D and *Second Report and Order*, CC Docket 87-313, October 4, 1990, Appendix D.

correspondence provides some confirmation that—at the level of aggregation of the entire firm—the historical price method and the direct TFP method yield similar results, as they should under the principles of duality.[46]

In summary, although economic theory suggests that prices and quantities can be used symmetrically to calculate productivity growth, there are serious practical concerns with historical price-based methods in these circumstances. Price-based methods can replicate accurately the outcome of historical regulation on prices and can determine an *X* that will assure customers that real price growth will be slower under price regulation than it had been under the historical regulatory regime. However, to give economic support to the historical price method requires (i) that prices be adjusted to undo the multitude of regulatory changes over time and (ii) that the analysis be undertaken at the level of the total firm rather than interstate services or individual services.[47] When that analysis is undertaken, we see that the historical price method yields approximately the same historical value of the X-Factor as obtained from the direct measurement of TFP growth based on input and output quantities.

[46] Note that if the short run point estimate of the input price differential were added to Dr. Christensen's TFP differential, the correspondence between the direct and dual estimates of industry productivity would disappear. This fact implies that only the long-run adjustment for differences in input price growth rates—essentially zero—is consistent with both the empirical evidence and the implications of duality.

[47] Note that measures of the historical productivity offset based on carrier access prices proposed in this Docket do not give such support because they are undertaken for only a subset of the LEC's services.

VI. The Consumer Productivity Dividend

Paragraphs 94-95 of the *FFN* note that a consumer productivity dividend (CPD) was originally added to the historical X factor (calculated prior to price regulation) to ensure that customers benefited from the anticipated increase in the rate of growth of TFP stemming from the adoption of price cap regulation. The *FFN* then asks if a CPD should again be added to an historical X factor measured over a period in which price cap regulation were in force. There are at least two reasons why—irrespective of the announced level of the productivity offset—a continued or additional CPD is not warranted. First, adding a CPD to an historical X factor measured over a period that includes price cap regulation would effectively double-count expected productivity gains from regulatory reform. Second, interstate price caps are currently approximately 2.5 percent lower than would otherwise have been because of the 0.5 percent CPD put in place at the beginning of price cap regulation for LECs. It is unclear why a shift to an improved form of regulation in the past would continue to yield additional efficiencies in the future. One might think that a one-time reduction in prices should be required to match a one-time reduction in costs from improved regulation. However, because it is built in as part of the productivity offset, the interstate CPD automatically increases over time. Indeed, since 1991, some five years of a CPD are embedded in the LECs' current rates.

VII. Conclusion

Three important areas of Commission concern are addressed in this study. First, evidence regarding the magnitude and uncertainty of the measured input price differential in a price cap plan suggests that point estimates calculated over a relatively short period of time are too unreliable to support their use in a mechanical formula. If a productivity target were increased to account for the post-divestiture difference in LEC and U.S. input price growth, the LECs would be doubly penalized when interest rates begin to rise and LEC input prices begin to rise more rapidly than those of the U.S. as a whole.

Second, use of historical TFP measures to determine the productivity offset in the price adjustment formula is reasonable. Productivity growth must be calculated at the level of the entire firm. Efforts to calculate service-specific productivity growth are misguided because the production function for telecommunications services is not separable for interstate and intrastate services, for regulated and nonregulated services, or for finer disaggregates of services. It is not possible to estimate service-specific TFP growth. Similarly, adjustments to total firm measures of productivity growth to account for differential output growth or contribution by service are also improper because there is no underlying difference in productivity growth rates across services for these adjustments to approximate.

Third, while calculating productivity growth from price or earnings data is possible in theory, it is more academic than practical. The Historical Revenue method requires that accounting measures of earnings and depreciation correspond to economic concepts and that price cap regulation have been applied correctly and consistently over the historical period. Similarly, the Historical Price Method requires that the price data be adjusted to keep measured economic earnings constant, and errors in those adjustments are likely to have a larger effect on measured TFP growth than when direct, quantity-based measures of productivity growth are calculated. But the main drawback to both approaches is that—despite appearances—they cannot produce meaningful productivity growth measures for LEC interstate services. Productivity growth for LEC interstate services calculated by these methods entails tacit assignments of fixed common costs to particular services, so that the resulting measure of productivity growth is as arbitrary as the undefined concept—the productivity growth of a subset of services connected through fixed common costs—it attempts to quantify. Such measures have no theoretical support in economics and can play no useful role in the measurement of productivity growth to set the parameters of a price cap plan.

REGRESSION: TELEPHONE INPUT PRICE GROWTH - CHRISTENSEN 1 DATA

Year A	LEC Input Price Change B	U.S. Input Price Change C	Divestiture Binary Dummy E	Moody's Pub Util Bonds D	1990-2 Dummy E
1949	3.2%	-1.0%	0	2.66%	0
1950	5.1%	6.3%	0	2.62%	0
1951	8.8%	7.9%	0	2.86%	0
1952	8.8%	1.2%	0	2.96%	0
1953	2.4%	3.7%	0	3.20%	0
1954	1.9%	0.6%	0	2.90%	0
1955	5.4%	6.6%	0	3.06%	0
1956	1.7%	0.7%	0	3.36%	0
1957	-1.1%	3.7%	0	3.89%	0
1958	3.3%	0.5%	0	3.79%	0
1959	5.4%	7.0%	0	4.38%	0
1960	4.2%	-0.6%	0	4.41%	0
1961	3.9%	3.6%	0	4.35%	0
1962	2.2%	4.4%	0	4.33%	0
1963	1.0%	3.8%	0	4.26%	0
1964	6.0%	4.5%	0	4.40%	0
1965	0.5%	5.7%	0	4.49%	0
1966	1.1%	4.6%	0	5.13%	0
1967	1.9%	2.0%	0	5.51%	0
1968	4.2%	4.4%	0	6.18%	0
1969	2.1%	3.7%	0	7.03%	0
1970	3.8%	3.3%	0	8.04%	0
1971	4.2%	6.8%	0	7.39%	0
1972	8.0%	7.2%	0	7.21%	0
1973	0.6%	6.3%	0	7.44%	0
1974	5.9%	4.2%	0	8.57%	0
1975	14.2%	9.4%	0	8.83%	0
1976	10.7%	9.1%	0	8.43%	0
1977	6.1%	8.6%	0	8.02%	0
1978	7.6%	7.8%	0	8.73%	0
1979	7.2%	8.2%	0	9.63%	0
1980	14.6%	6.6%	0	11.94%	0
1981	11.6%	9.9%	0	14.17%	0
1982	12.1%	3.7%	0	13.79%	0
1983	12.8%	5.6%	0	12.04%	0
1984	1.8%	7.4%	1	12.71%	0
1985	0.1%	4.0%	1	11.37%	0
1986	1.3%	3.8%	1	9.02%	0
1987	1.7%	3.1%	1	9.38%	0
1988	-3.2%	4.4%	1	9.71%	0
1989	-3.7%	4.1%	1	9.26%	0
1990	11.9%	4.2%	1	9.32%	1
1991	1.3%	2.9%	1	8.77%	1
1992	4.4%	5.1%	1	8.14%	1

Permanent Shift Hypothesis (Bush-Uretsky)

Constant		-0.0027	
Std Err of Y Est		0.0347	
R Squared		0.4322	
No. of Observations		44	
Degrees of Freedom		40	
	US IPr	Divestiture	Moody
X Coefficient(s)	0.3402	-0.0579	0.6489
Std Err of Coef.	0.2338	0.0152	0.2093
t-Statisic	1.4553	-3.8142	3.1007
F-statistic (3,40)	10.1512		

Temporary Shift Hypothesis

Constant		-0.0061		
Std Err of Y Est		0.0309		
R Squared		0.5600		
No. of Observations		44		
Degrees of Freedom		39		
	US IPr	Divestiture	Moody	1990-1992
X Coefficient(s)	0.3209	-0.0851	0.7174	0.0740
Std Err of Coef.	0.2085	0.0158	0.1877	0.0220
t-Statisic	1.5392	-5.3981	3.8225	3.3658
F-statistic (4,39)	12.4114			

Source: CC: Docket 94-1, First Report and Order, Released April 7, 1995. Appendix F. Christensen Affidavit Data

REGRESSION: TELEPHONE INPUT PRICE GROWTH - CHRISTENSEN 2 DATA

Year	LEC Input Price Change	U.S. Input Price Change	Divestiture Binary Dummy	Yield on Moody's Pub Util Bonds	1990-2 Dummy
A	B	C	D	E	F
1960	2.4%	1.7%	0	4.41%	0
1961	4.0%	2.9%	0	4.35%	0
1962	3.1%	4.5%	0	4.33%	0
1963	4.9%	3.9%	0	4.26%	0
1964	2.4%	5.4%	0	4.40%	0
1965	2.4%	4.4%	0	4.49%	0
1966	1.5%	5.5%	0	5.13%	0
1967	5.0%	2.8%	0	5.51%	0
1968	6.1%	6.4%	0	6.18%	0
1969	2.7%	4.0%	0	7.03%	0
1970	4.0%	3.2%	0	8.04%	0
1971	6.5%	6.6%	0	7.39%	0
1972	7.6%	6.0%	0	7.21%	0
1973	6.6%	8.6%	0	7.44%	0
1974	4.8%	4.2%	0	8.57%	0
1975	9.3%	8.5%	0	8.83%	0
1976	9.2%	9.2%	0	8.43%	0
1977	4.8%	7.3%	0	8.02%	0
1978	7.3%	7.0%	0	8.73%	0
1979	2.9%	7.7%	0	9.63%	0
1980	6.9%	7.0%	0	11.94%	0
1981	11.0%	9.5%	0	14.17%	0
1982	9.3%	3.1%	0	13.79%	0
1983	13.7%	6.2%	0	12.04%	0
1984	1.8%	6.5%	1	12.71%	0
1985	0.1%	4.0%	1	11.37%	0
1986	1.3%	3.8%	1	9.02%	0
1987	1.7%	3.2%	1	9.38%	0
1988	-3.2%	4.6%	1	9.71%	0
1989	-3.7%	4.2%	1	9.26%	0
1990	11.9%	4.3%	1	9.32%	1
1991	1.3%	2.9%	1	8.77%	1
1992	4.4%	5.1%	1	8.14%	1

Permanent Shift Hypothesis (Bush-Uretsky)

Constant		-0.0046	
Std Err of Y Est		0.0308	
R Squared		0.4440	
No. of Observations		33	
Degrees of Freedom		29	
	US IPr	Divestiture	Moody
X Coefficient(s)	0.3140	-0.0480	0.5794
Std Err of Coef.	0.3179	0.0144	0.2350
t-Statistic	0.9878	-3.3365	2.4653
F-statistic (3,29)	7.7208		

Temporary Shift Hypothesis

Constant		-0.0111		
Std Err of Y Est		0.0247		
R Squared		0.6553		
No. of Observations		33		
Degrees of Freedom		28		
	US IPr	Divestiture	Moody	1990-1992
X Coefficient(s)	0.2774	-0.0752	0.6916	0.0731
Std Err of Coef.	0.2549	0.0133	0.1903	0.0177
t-Statistic	1.0881	-5.6677	3.6345	4.1423
F-statistic (4,28)	13.3067			

Source: CC: Docket 94-1, First Report and Order, Released April 7, 1995. Appendix F, NERA Data

REGRESSION: INPUT PRICE DIFFERENTIAL - CHRISTENSEN 1 DATA

Year	LEC-US Input Price Growth	Divest Binary Dummy	Moody's Pub Util Bonds	1990-2 Dummy
A	B	C	D	E
1949	4.2%	0	2.66%	0
1950	-1.2%	0	2.62%	0
1951	0.9%	0	2.86%	0
1952	7.4%	0	2.96%	0
1953	-1.3%	0	3.20%	0
1954	1.3%	0	2.90%	0
1955	-1.2%	0	3.06%	0
1956	1.0%	0	3.36%	0
1957	-4.8%	0	3.89%	0
1958	2.8%	0	3.79%	0
1959	-1.6%	0	4.38%	0
1960	4.8%	0	4.41%	0
1961	0.3%	0	4.35%	0
1962	-2.2%	0	4.33%	0
1963	-2.8%	0	4.26%	0
1964	1.5%	0	4.40%	0
1965	-5.2%	0	4.49%	0
1966	-3.5%	0	5.13%	0
1967	-0.1%	0	5.51%	0
1968	-0.2%	0	6.18%	0
1969	-1.6%	0	7.03%	0
1970	0.5%	0	8.04%	0
1971	-2.6%	0	7.39%	0
1972	0.8%	0	7.21%	0
1973	-5.7%	0	7.44%	0
1974	1.7%	0	8.57%	0
1975	4.8%	0	8.83%	0
1976	1.6%	0	8.43%	0
1977	-2.5%	0	8.02%	0
1978	-0.2%	0	8.73%	0
1979	-1.0%	0	9.63%	0
1980	8.0%	0	11.94%	0
1981	1.7%	0	14.17%	0
1982	8.4%	0	13.79%	0
1983	7.2%	0	12.04%	0
1984	-5.6%	1	12.71%	0
1985	-3.9%	1	11.37%	0
1986	-2.5%	1	9.02%	0
1987	-1.4%	1	9.38%	0
1988	-7.6%	1	9.71%	0
1989	-7.8%	1	9.26%	0
1990	7.7%	1	9.32%	1
1991	-1.6%	1	8.77%	1
1992	-0.7%	1	8.14%	1

Permanent Shift Hypothesis (Bush-Uretsky)

Constant		-0.0157	
Std Err of Y Est		0.0375	
R Squared		0.1702	
No. of Observations		44	
Degrees of Freedom		41	
	Divestiture	Moody	
X Coefficient(s)	-0.0440	0.3464	
Std Err of Coef.	0.0155	0.1944	
t-Statistic	-2.8330	1.7818	
F-statistic (2,41)	4.2036		

Temporary Shift Hypothesis

Constant		-0.0194	
Std Err of Y Est		0.0344	
R Squared		0.3179	
No. of Observations		44	
Degrees of Freedom		40	
	Divestiture	Moody	1990-1992
X Coefficient(s)	-0.0701	0.4045	0.0721
Std Err of Coef.	0.0168	0.1796	0.0245
t-Statistic	-4.1737	2.2527	2.9429
F-statistic (3,40)	6.2128		

Source: CC: Docket 94-1, First Report and Order, Released April 7, 1995. Appendix F, Christensen Affidavit Data

REGRESSION: INPUT PRICE DIFFERENTIAL - CHRISTENSEN 2 DATA

Year	LEC-US Input Price Growth	Divestiture Binary Dummy	Yield on Moody's Pub Util Bonds	1990-2 Dummy
A	B	B	D	E
1960	0.7%	0	4.41%	0
1961	1.1%	0	4.35%	0
1962	-1.4%	0	4.33%	0
1963	1.0%	0	4.26%	0
1964	-3.0%	0	4.40%	0
1965	-2.0%	0	4.49%	0
1966	-4.0%	0	5.13%	0
1967	2.2%	0	5.51%	0
1968	-0.3%	0	6.18%	0
1969	-1.3%	0	7.03%	0
1970	0.8%	0	8.04%	0
1971	-0.1%	0	7.39%	0
1972	1.6%	0	7.21%	0
1973	-2.0%	0	7.44%	0
1974	0.6%	0	8.57%	0
1975	0.8%	0	8.83%	0
1976	0.0%	0	8.43%	0
1977	-2.5%	0	8.02%	0
1978	0.3%	0	8.73%	0
1979	-4.8%	0	9.63%	0
1980	-0.1%	0	11.94%	0
1981	1.5%	0	14.17%	0
1982	6.2%	0	13.79%	0
1983	7.5%	0	12.04%	0
1984	-4.7%	1	12.71%	0
1985	-3.9%	1	11.37%	0
1986	-2.5%	1	9.02%	0
1987	-1.5%	1	9.38%	0
1988	-7.8%	1	9.71%	0
1989	-7.9%	1	9.26%	0
1990	7.6%	1	9.32%	1
1991	-1.6%	1	8.77%	1
1992	-0.7%	1	8.14%	1

Permanent Shift Hypothesis (Bush-Uretsky)

	Divestiture	Moody
Constant		-0.0251
Std Err of Y Est		0.0327
R Squared		0.1848
No. of Observations		33
Degrees of Freedom		30
X Coefficient(s)	-0.0338	0.3419
Std Err of Coef.	0.0135	0.2200
t-Statistic	-2.4935	1.5543
F-statistic (2,30)	3.4001	

Temporary Shift Hypothesis

	Divestiture	Moody	1990-1992
Constant		-0.0325	
Std Err of Y Est		0.0275	
R Squared		0.4395	
No. of Observations		33	
Degrees of Freedom		29	
X Coefficient(s)	-0.0596	0.4390	0.0714
Std Err of Coef.	0.0135	0.1874	0.0197
t-Statistic	-4.4281	2.3422	3.6299
F-statistic (3,29)	7.5787		

Source: CC: Docket 94-1, First Report and Order, Released April 7, 1995. Appendix F, NERA Data

EXHIBIT 1a

COMPETITIVE ACCESS PROVIDERS - Summary by State and City as of 11'95

State	City	Competitor - Existing	Competitor - Planned
1) Arizona	Phoenix	Teleport Comm Group (TCG) IntelCom Group (ICG) GST Telecom Electric Lightwave (ELI) MFS Communications (MFS)	
	Tucson		Amer. Comm. Srvs. (ACSI) Brooks Fiber Comm. GST Telecom
2) Colorado	Color. Springs	ICG	
	Denver	ICG TCG MFS	MCImetro
	Boulder	ICG	MFS TCG
3) Idaho	Boise		Phoenix FiberLink of Idaho
4) Iowa	Des Moines	McLeod	
	Cedar Rapids	McLeod	
5) Minnesota	Minneapolis	MFS Paragon Cable/ Fibrcom	
6) Montana			
7) Nebraska	Omaha	TCG	
8) New Mexico	Albuquerque		ACSI Brooks GST Telecom of NM Phoenix FiberLink of NM
	Las Cruces		GST Telecom of NM
	Farmington		GST Telecom of NM
	Santa Fe		GST Telecom of NM
9) No. Dakota			
10) Oregon	Portland	ELI Paragon Cable Pacnet	MCImetro MFS Digital Direct
11) So. Dakota			
12) Utah	Salt Lake City	ELI	Phoenix FiberLink of Utah Qwest Communications
13) Washington	Seattle	TCG MFS ELI	MCImetro
	Spokane		FiberLink/Tel-West
14) Wyoming			

- This information represents publicly available information collected by U S WEST